

## **Sampling Methods and Equipment**

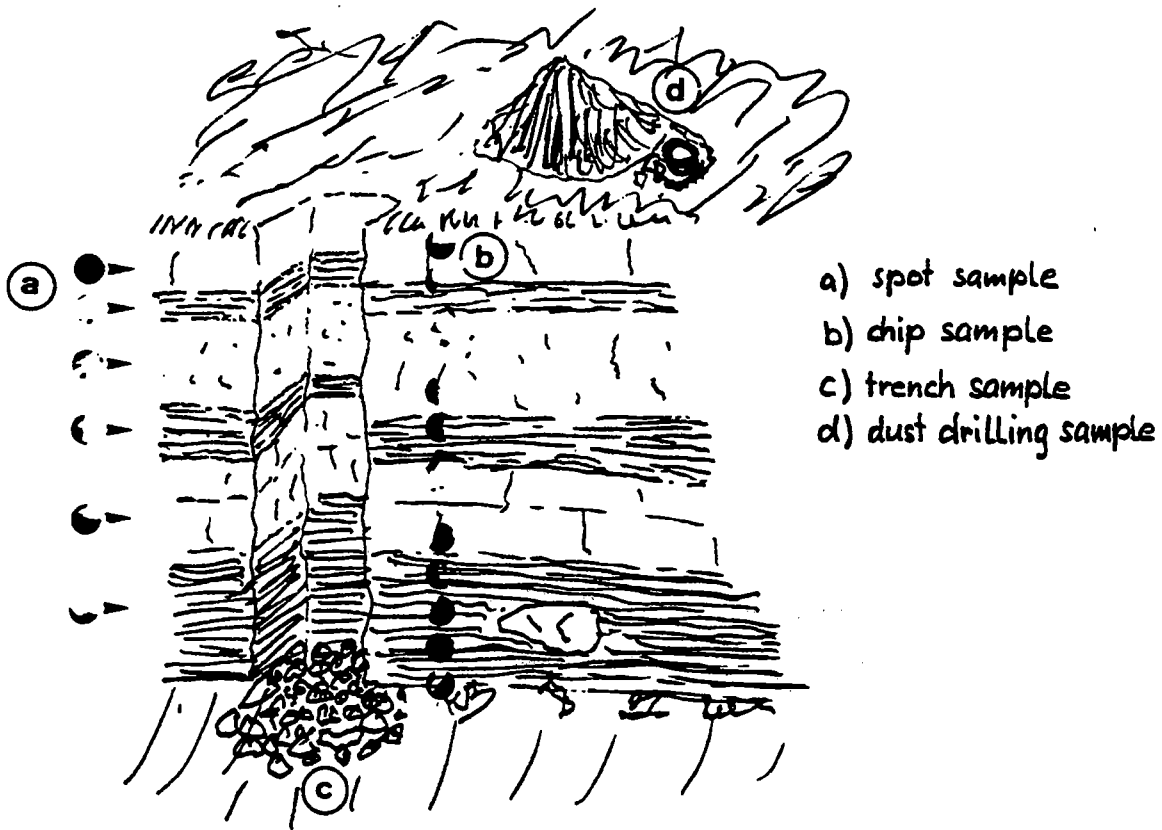
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**1. SAMPLING OF STATIONARY MATERIALS**

Sampling of stationary material should, whenever possible, be replaced by sampling on conveyed material. In a number of cases, however, sampling of stationary material cannot be avoided. Such cases are reviewed in the following:

**1.1 Field sampling**

The mineralogical and chemical composition of sedimentary rocks generally vary far more rapidly in the vertical direction (stratigraphic sequence) than they do in the horizontal direction of the layer; therefore a vertically oriented sampling is required.



**1.1.1 Surface sampling**

In the sequence of increasing reliability, the following methods of surface sampling on an exposed face can be applied:

**a) unweighted spot sample**

for each rock layer of a rock complex only one sample is taken at a definite spot.

Information: only a rough judgement of the investigated material possible.

**aa) weighted spot samples**

more reliable information is achieved as the spot samples of each layer are weighted up according to their stratigraphic thickness.



Core drilling sample

the core sample is obtained by rotary drilling with core barrel tipped with a steel or diamond bit. This method can also be applied below the water table. A representative sample for chemical-mineralogical investigations can only be guaranteed on a core recovery of over 90%. The cores can also be used to determine the technological properties of the rock.

**1.2 Sampling of bulk cement**

In addition to sampling at the material surface, it is also required to collect material from the interior using a tube sampler. For cement sampling tube samplers are often specified in the standard specifications e.g. ASTM C183.

**2. SAMPLING OF CONVEYED MATERIALS**

This term applies to all types of material which are transported continuously; for instance gravel on a belt conveyor, meal in an airslide or slurry in a slurry pipe.

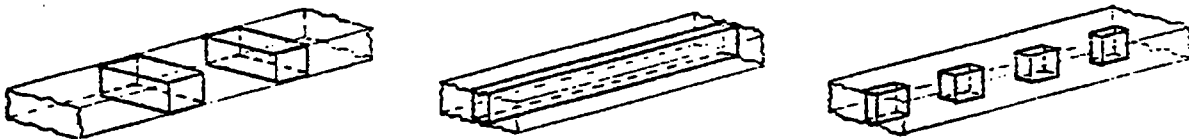
There are three principal ways in which a material can be taken from a material flow:

- 1) Transverse sample consists of the whole of the material flow during short, predetermined time interval.
- 2) Longitudinal sample consists of a part of the material flow which is continuously deflected from the main stream.
- 3) Quasi-point sample is created by the branching off of a part of the material flow during a certain period of time.

A visual impression of these three categories can be obtained by imagining the samples taken from a stationary belt conveyor.



or drawn 3 - dimensionally:



**2.1 Evaluation of the 3 categories**

**2.1.1 Transverse samples**

This sampling method is, in principle, correct as the average value of the individual collected samples is almost the true average value of the "lot". The term "lot" should be understood as that quantity to which the measurements refer, as for example the heap of a mixing bed, a shipload, a rail wagon, a silo etc.

**2.1.2 Longitudinal samples**

If all particle sizes were represented in their correct relationship in that part of the stream sampled, this type of sampling would yield a true picture of the "lot". In reality, however, the force of gravity causes a segregation of the particle sizes to a lesser or greater extent, and therefore excludes the fulfillment of the conditions mentioned above.

**2.1.3 Quasi-point samples**

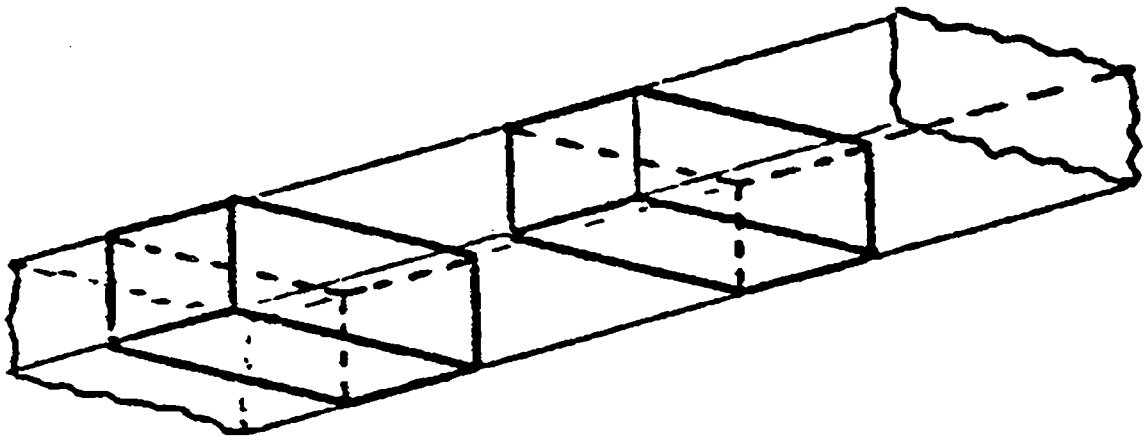
This type of sample is only a combination of the preceding two types. It incorporates no new advantages, but embodies the disadvantages of both the other categories.

The transversal sample therefore appears to be the only one promising success. It is the only one that can fulfill the condition of having an equal chance of sampling all the particle size fractions.

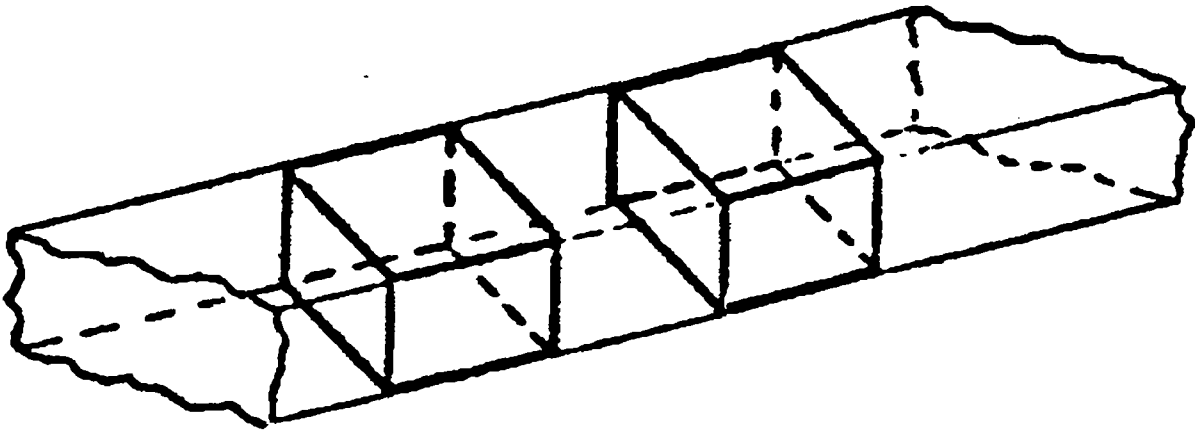
**2.2 Various possibilities of collecting a transverse sample**

The various possibilities are illustrated below in the form of a three-dimensional illustration of the material flow.

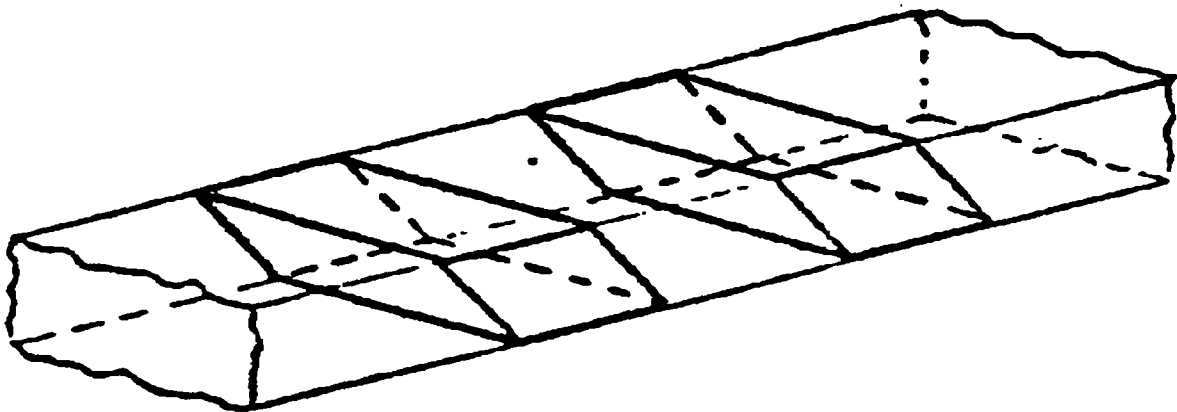
A) Rectangular cut



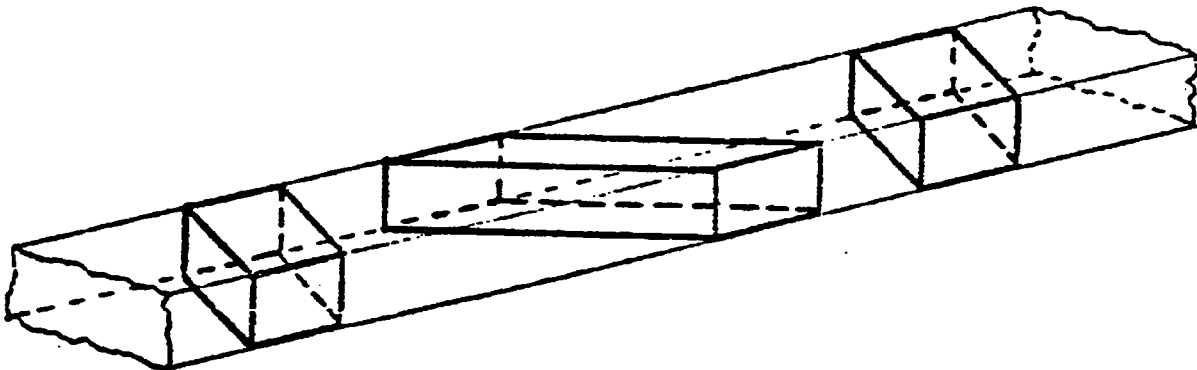
B) Horizontal inclined cut



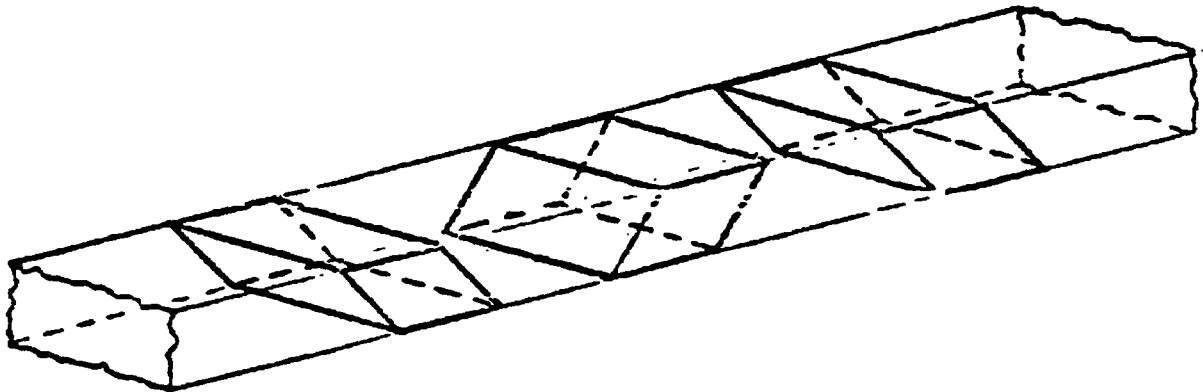
C) Vertical inclined cut



D) Alternating horizontal inclined cut



E) Alternating vertical inclined cut



From a theoretical viewpoint, these five cuts are of comparable value. The differences lie in the ease of their practical application.

Type A): Can only be realised on a stationary conveyor belt or by means of a travelling sampler.

Type B): Can be realised by means of a rotating sampler. The sampling aperture always moves in the same direction through the material.

Type C): A bucket wheel sampler belongs to this type.

Type D): This is the most commonly found type of equipment. The reciprocating slit vessel and the reciprocating chute types are typical examples.

Type E): This can only be realised by a radially mounted slit vessel; this type of equipment is generally too large.

### **2.3 Deviations from the ideal case**

- 1) The particles do not drop one behind the other, but in a more or less compact stream and can therefore influence each other.
- 2) The particles make contact, not with a stationary separating wall, but with a moving one and can therefore be deflected at the moment of impact.
- 3) The opening of the sampler is not of an infinite size. Processes on the one separating wall can therefore be influenced by those on the opposite one.
- 4) The separating walls are not infinitely thin and can be bent in the course of time.
- 5) The particles themselves can break on impact. This would be of importance only when a screen analysis is to be prepared from the sample.

The design of samplers must be aimed at overcoming all these difficulties. What form these solutions take and what important rules must be respected, is described in the next chapter.

**2.4 Rules for the sampler**

(1) Slit width and speed are inter-dependent.

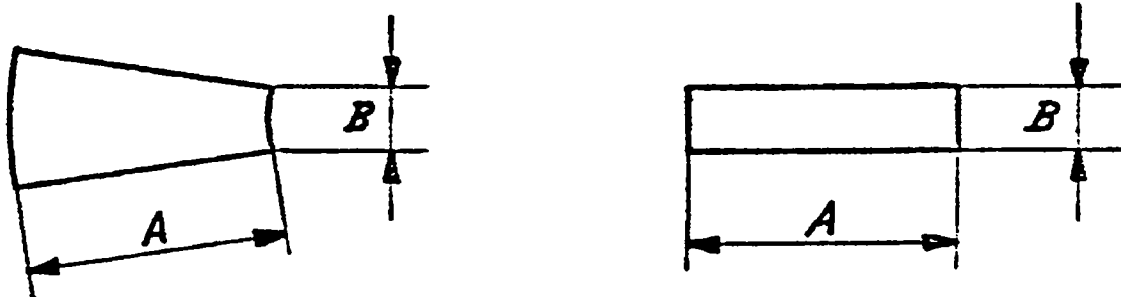
Width of slit  $B \geq 3 d + 10 \text{ mm}$

$d$  = diameter of the largest particle.

This ensures that even for fine meal, the width of the slit does not fall under 10 mm.

Speed  $w \geq 300 \text{ mm/s}$

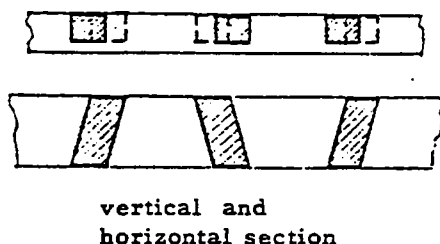
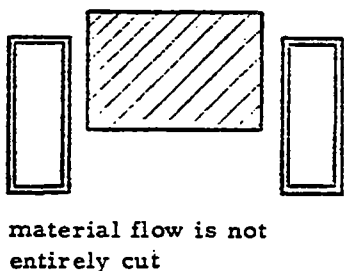
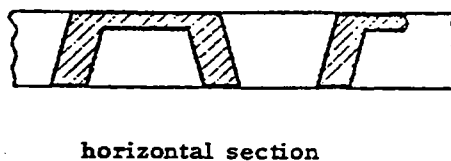
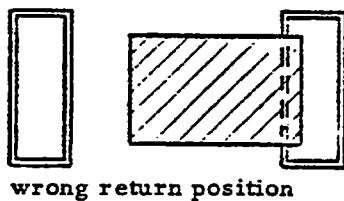
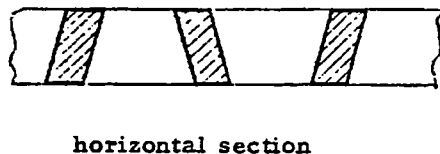
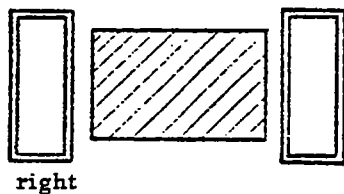
In special cases this can be increased to 400 mm/s, provided the slit width is increased to  $4 d + 10 \text{ mm}$ .



The conditions for the slit width must be respected for all slit dimensions.

(2) The edges of the sample apertures should be fitted with interchangeable sacrificial elements made of a wear resistant steel.

(3) The slit aperture must transverse the entire cross sectional area of the material flow. The return and stopping positions must be placed outside of this area.

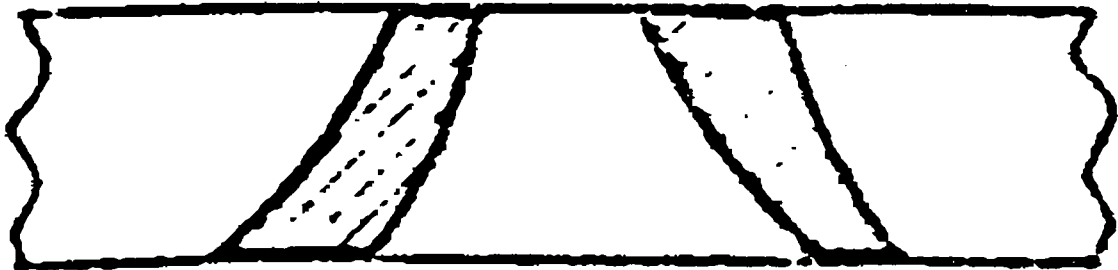




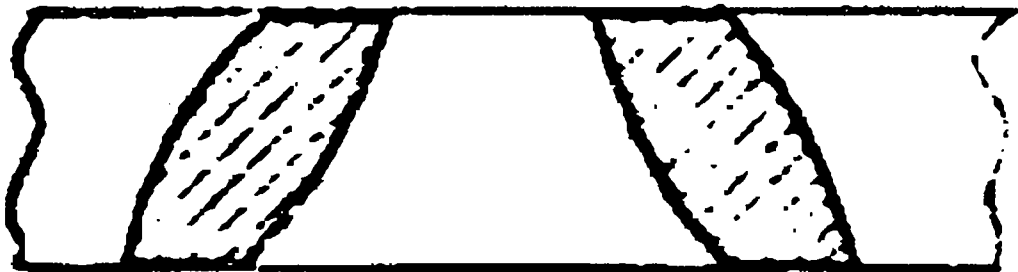
(4) The speed of the sampler during its journey through the material must be constant, during any single traverse as well as from one traverse to another.

- ◆ Quick starting electric motor with excess capacity. This drive is more suitable than a pneumatic or hydraulic cylinder, as the latter's speed cannot be easily regulated.
- ◆ An acceleration zone must be provided outside the material stream.

**Fig. Motor starts too slowly**

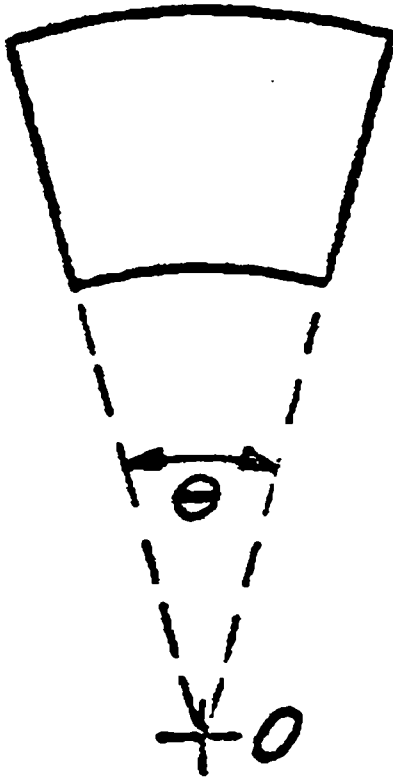


**Fig. Motor too weak**



(5) The shape of the sampler aperture must be suited to the movement.

- linear movement      —————>      the side walls must be parallel
- rotating movement      —————>      the side walls must be positioned radially.



right

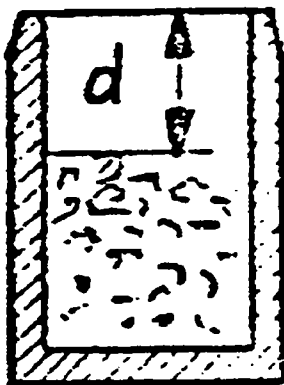


wrong

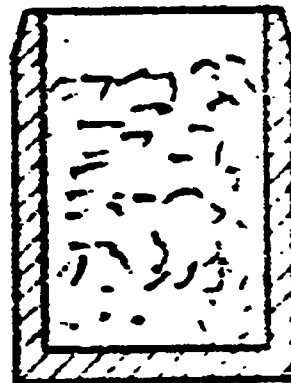
(6) Measures must be taken to avoid blocking and overflowing of the sampler.

Slit vessel cutter:

The capacity of the vessel should be twice as large as the nominal sample volume. In the filled vessel there should be a remaining free height equivalent to  $d$  or at least 100 mm.



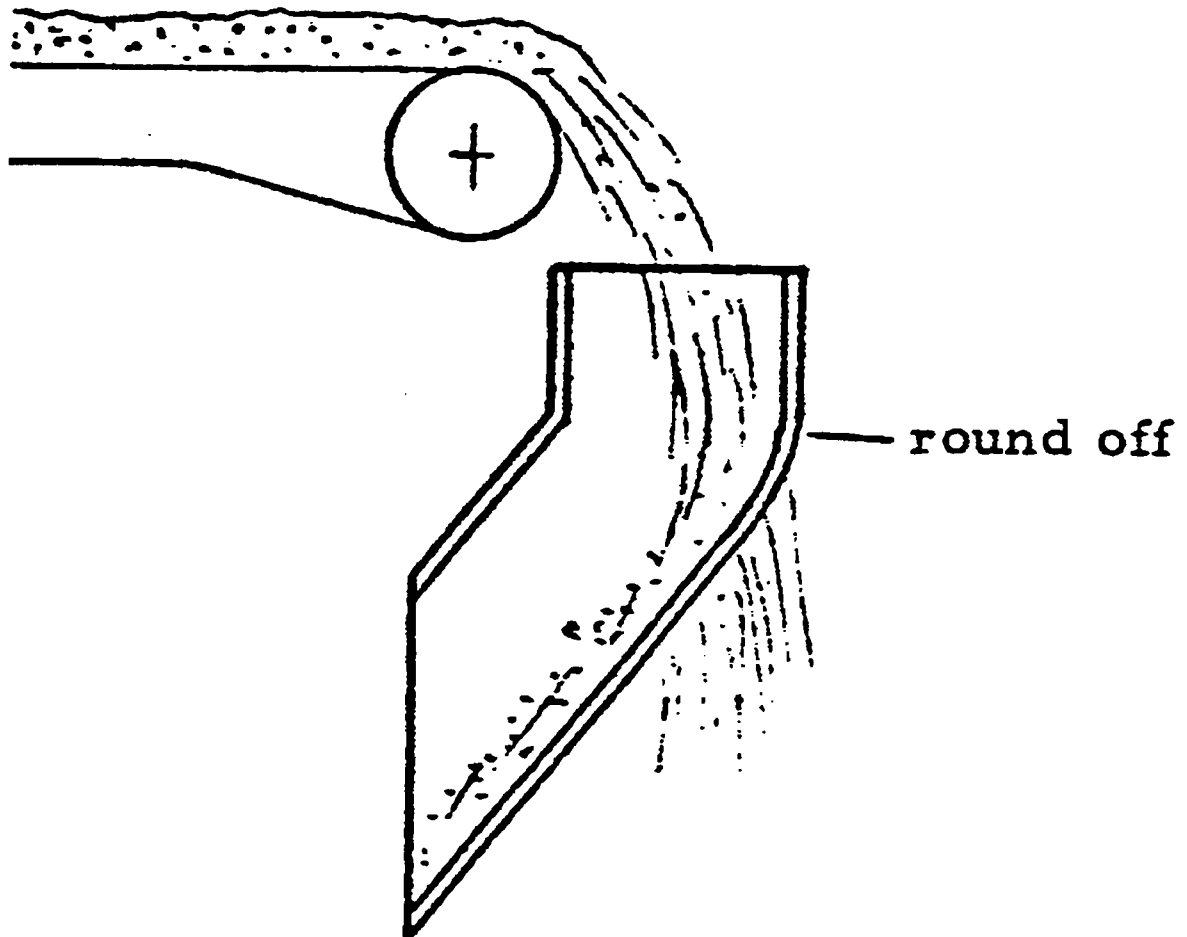
right



overfilled

Chute type cutter:

The vertical walls must be of sufficient height to prevent the "splashing" of particles. To ensure a flawless material extraction, the inclination of the walls must be chosen to suit the properties of the wettest materials encountered. Care should be taken that there are no obstructions. Corners, joints and protruding screws are often the cause of build-ups. Stainless steel should be used for sticky materials and if necessary provision for heating should be made.



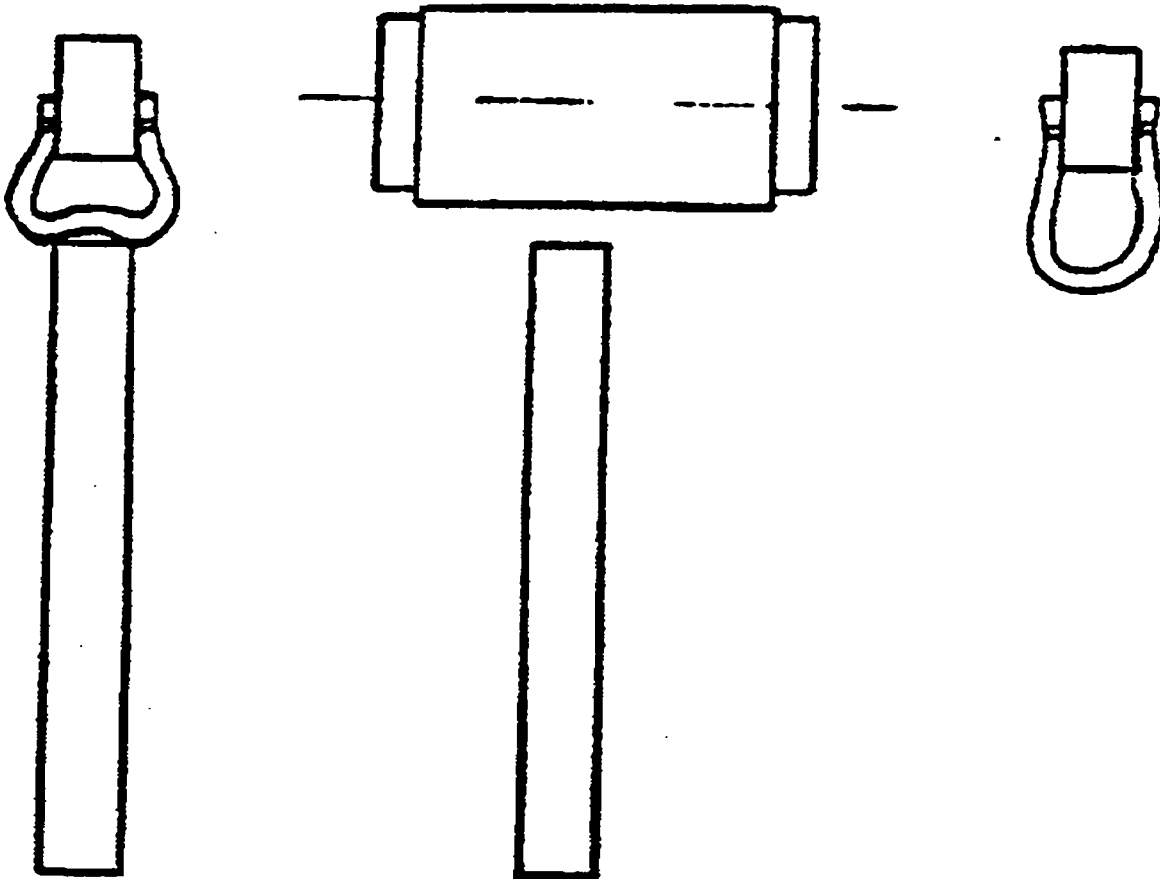
(7) The integrity of a sample must assured. Once a sample has been taken, it must be protected against all alterations, especially from the loss or addition of particles.

Loss of dust:

To reduce the drop height, the sampler should be mounted as close to the discharge point as possible. To avoid the formation of dust, the material can be slightly moistened before it reaches the sampler.

Addition of dust:

The whole sampling apparatus should be protected against dust. The aperture in the sampler can be closed by a lid in its static position.



(8) Calculation of the single sample volume  $m$ .

straight movement:

$$m = M \frac{B}{w}$$

$M$  = material flow [kg/s]

$B$  = slit aperture [m]

$w$  = speed [m/s]

rotary movement :

$$m = M \frac{\theta}{\varphi}$$

$\theta$  = aperture angle [rad]

$\varphi$  = angular speed [rad/s]

Note

A sampler designed in accordance with the previous rules has a lower rated capacity. It would be wrong to try to decrease the sample quantity by an increase in speed or by a reduction of the slit width.

**2.5 Recapitulation of sampling rules**

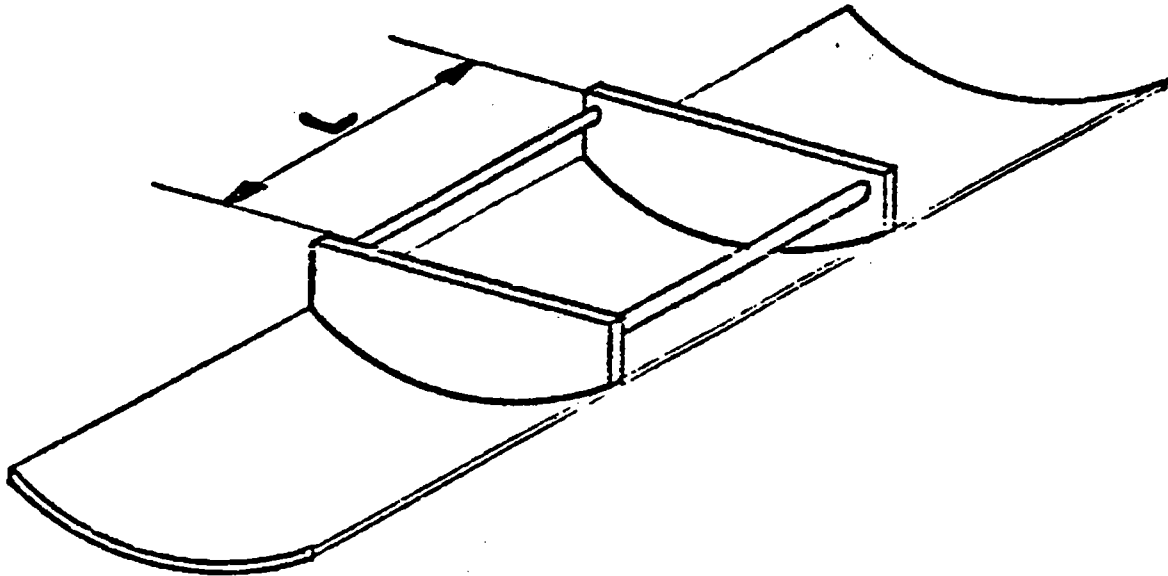
Fundamental principles which must be adhered to.	Principle No. 1 All sectors of the material stream must be sampled for an uniform time.	Principle No. 2 All particle sizes must have the same chance of being sampled.	Principle No. 3 There must be no alteration to the sample once it has been taken.
Measures to maintain the adherence to the fundamental principles.	1) Correct shape of the sampler aperture.  2) The whole of the material flow must be covered. Stopping points must lie outside the material flow.  3) The speed must stay constant during the traverse and from traverse to traverse.	1) Minimum slit size $3d + 10\text{mm}$  2) Speed generally less than 300 mm/s  3) Sampling to take place at a location where the fine particles are not thrown up as dust.	1) Prevention of blockages and overfilling.  2) No material loss.  3) No material additions.  4) Protection against any alteration of the composition.

**3. CRITICAL ANALYSIS OF THE BEST KNOWN SAMPLERS**

**3.1 Apparatus for transverse sampling with linear movement**

**3.1.1 Sampling from a stopped conveyor belt**

The sample is separated from the remaining material by a frame. This system is the closest approach to the theoretical model of a right-angle cut. As the material is stationary, L only needs to conform to the condition of  $L = 1.5 d + 100 \text{ mm}$ . The minimum sample therefore is smaller.



$$m1 = \frac{M}{v}(1.5d + 100mm)$$

m1 = minimum sample from the stationary belt

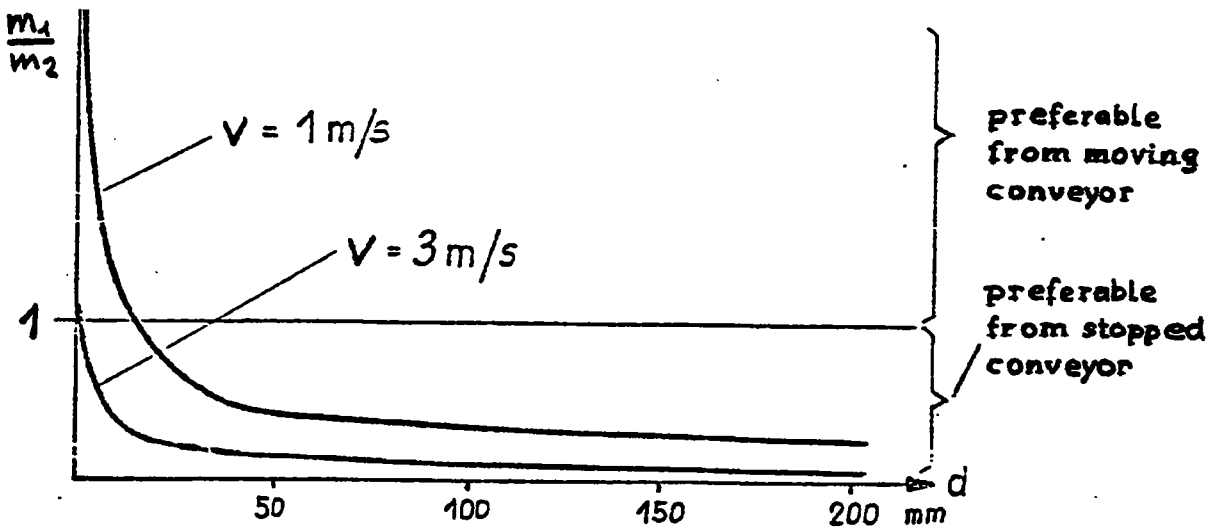
$$m2 = \frac{M}{w}(3d + 10mm)$$

m2 = smallest sample at material discharge point

$$\frac{m1}{m2} = \frac{w(1.5d + 0.1)}{v(3d + 0.01)}$$

v = belt speed

This function for w = 0.4 m/s appears as follows:

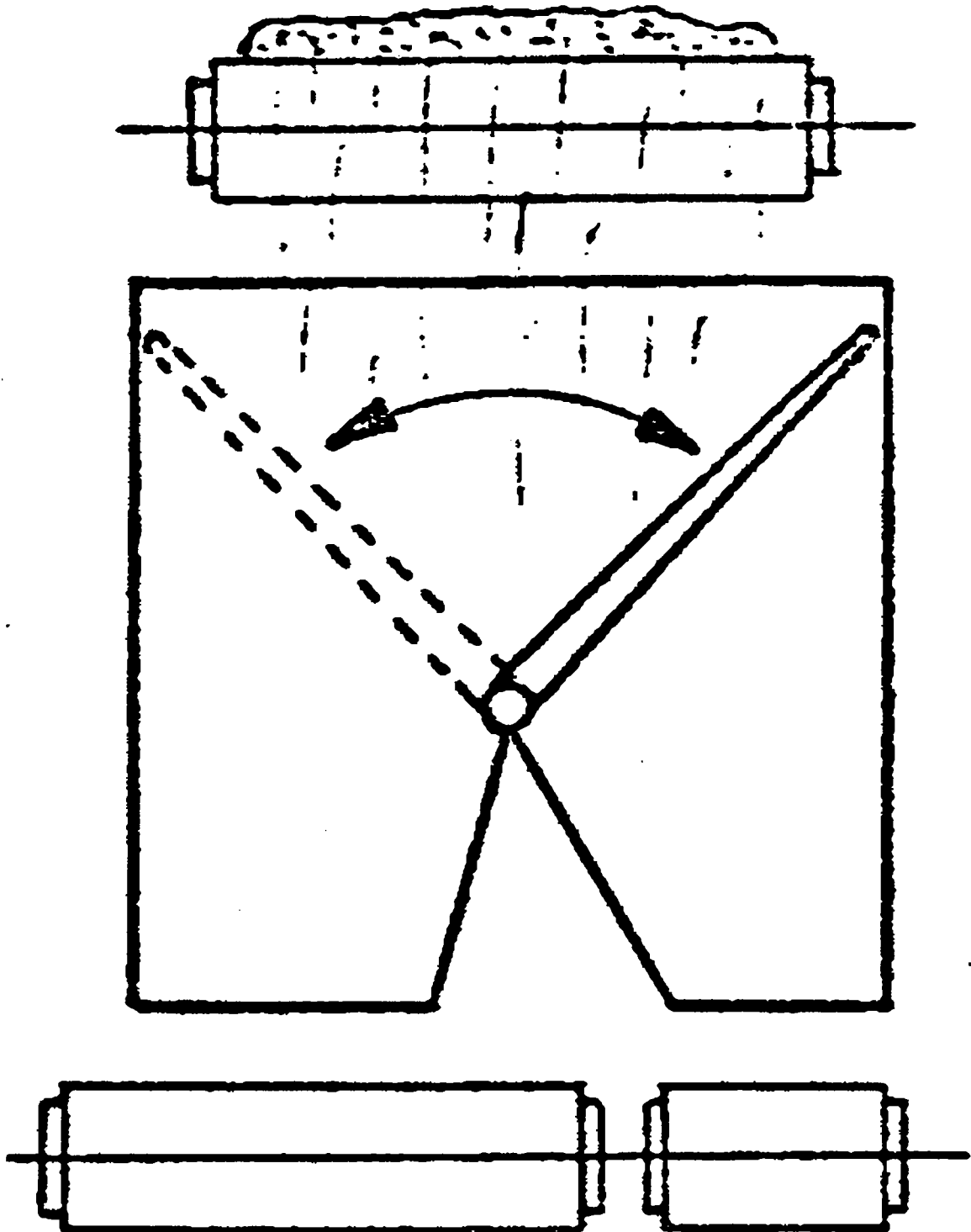


It can be observed that with larger particle sizes and at higher belt speeds the minimum sample quantity tends towards the sample from the stationary belt.

In practice it is, however, impossible to stop large conveyor belts for the purpose of sampling.

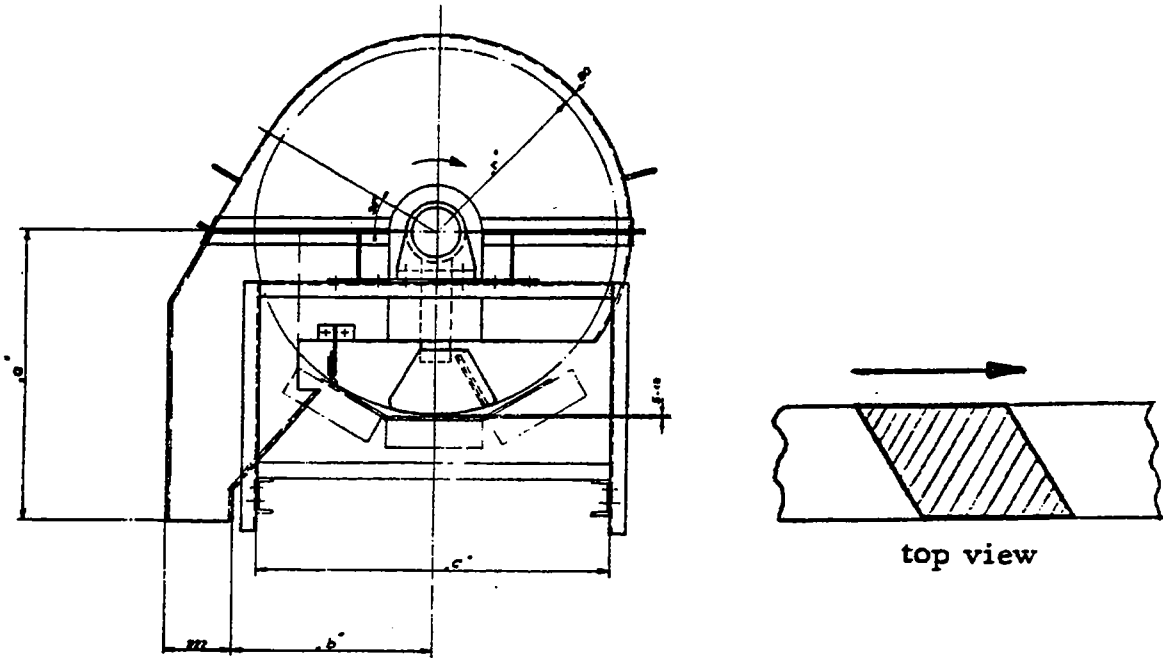
The sketch below shows a set-up which makes it possible to extract samples from a conveyor, fully automatically, without having to stop the main conveyor.

**Fig. Sampling belt**



For a certain pre-set time, the material is deflected by the flap onto the sample belt. The sample belt is stopped after the return of the flap. The sample can now be taken off the sample conveyor and the process can be easily automated. The speed of the sample conveyor can be freely selected and kept high. This makes it possible to reduce a sample down to 1/10th of the size of those from a sampler at the discharge end.

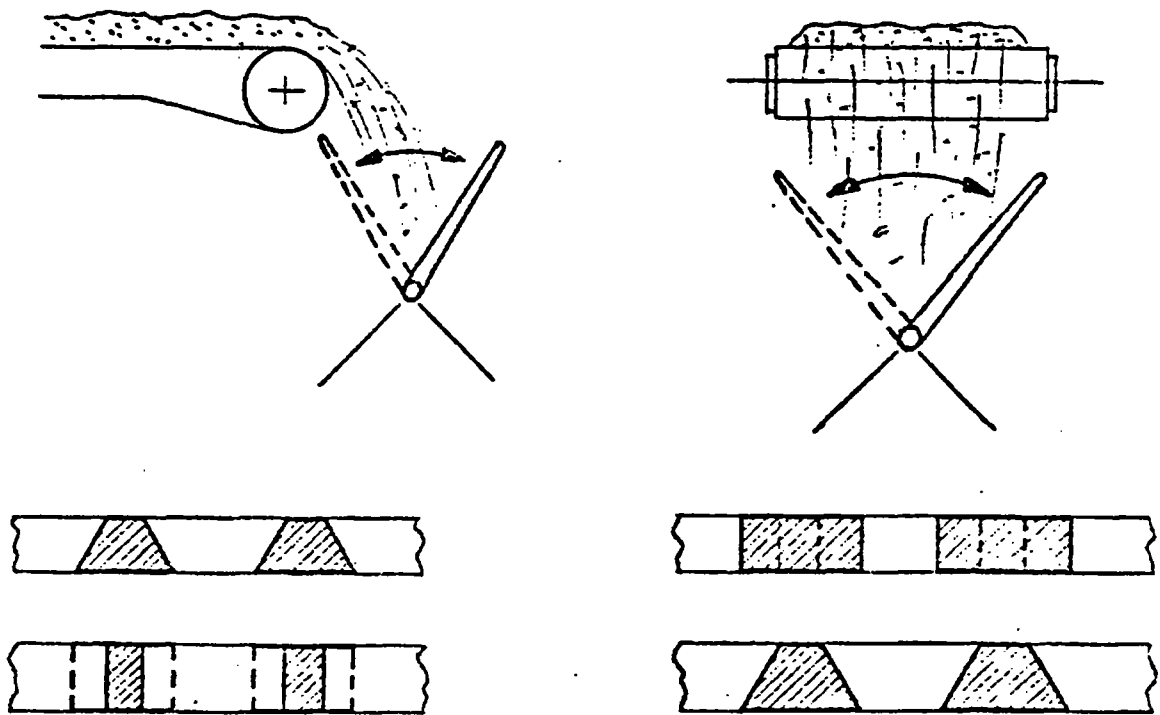
3.1.2 Hammer samplers



This equipment takes samples from a running conveyor. The hammer is designed as a scoop to ensure that the material is not Pushed aside. Brushes fixed to the end of the hammer clean the fine material from the belt. This type of sample is well-suited for non-sticky material.



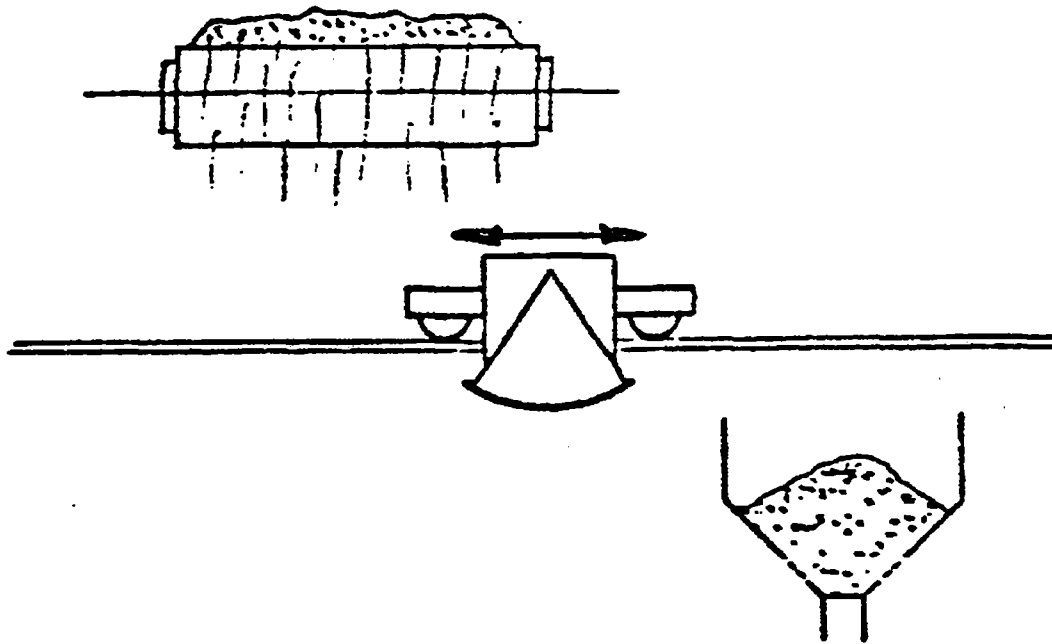
3.1.3 Sampler with flaps



The sectional illustrations show that the principle of uniform sampling of all material layers is not maintained. One might think that this systematic error could be avoided by a faster operation of the flap and by a longer residence time in the sampling position. In the first case, an unwelcome violent movement of the material would result whilst in the second case, the sample quantity will be very large or, with longer intervals, the integration error becomes unacceptable.

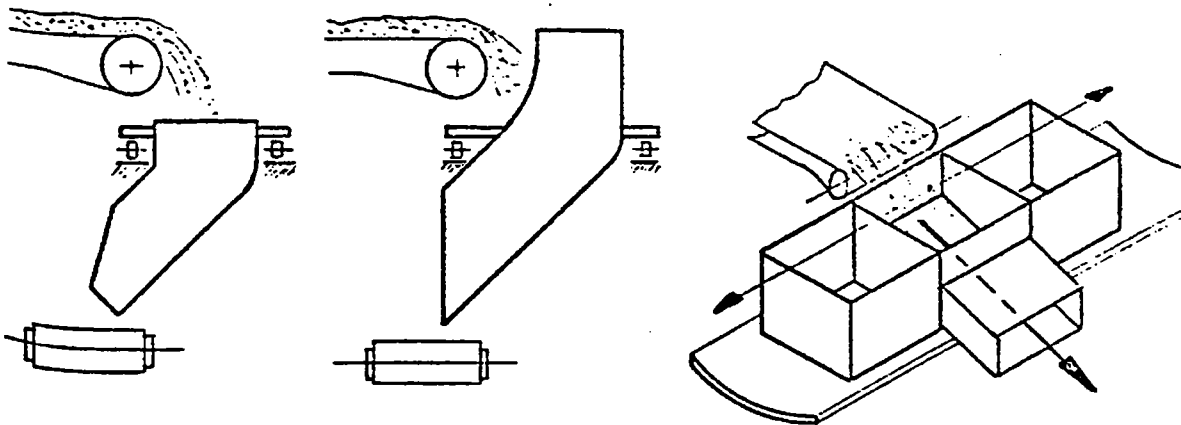
3.1.4 Slit vessel - sampler

Properly designed equipment of this type can fulfill all conditions.



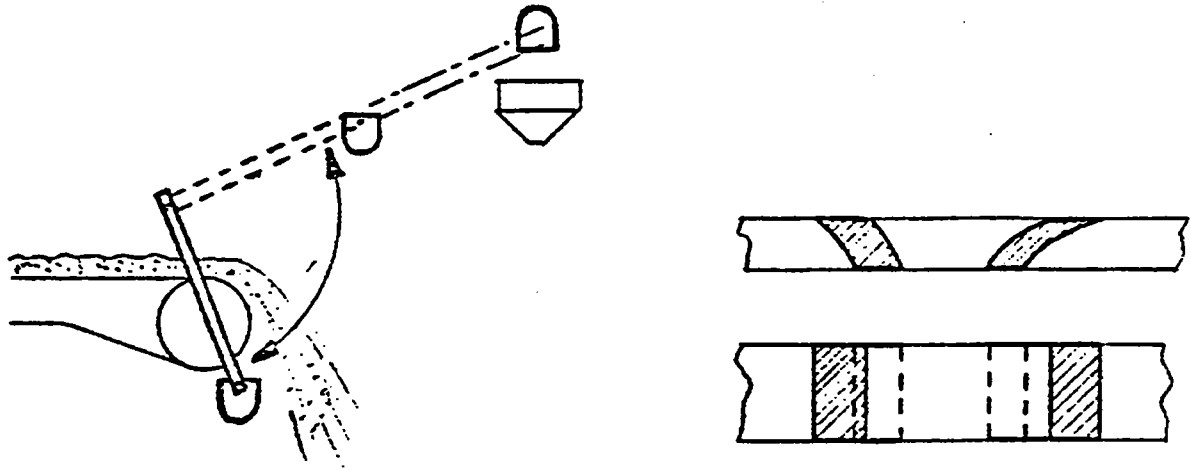
3.1.5 Chute sampler

The chute sampler, like the slit vessel sampler fulfills all require meets. It is suitable for the sampling of slurry as well as of dry material. The chute is of a simpler design than the slit vessel, but requires more headroom.



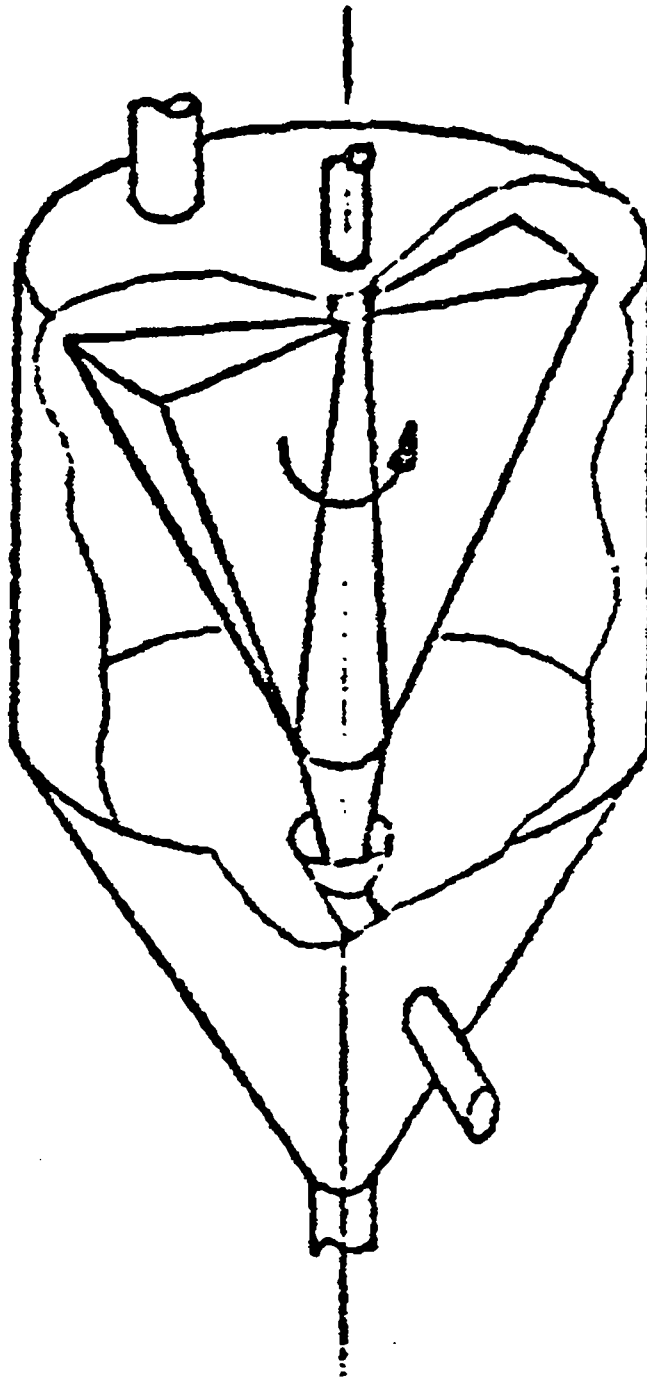
**3.2 Equipment for Transverse Sampling with a Rotary Motion**

**3.2.1 Slit vessel on a radial swing**



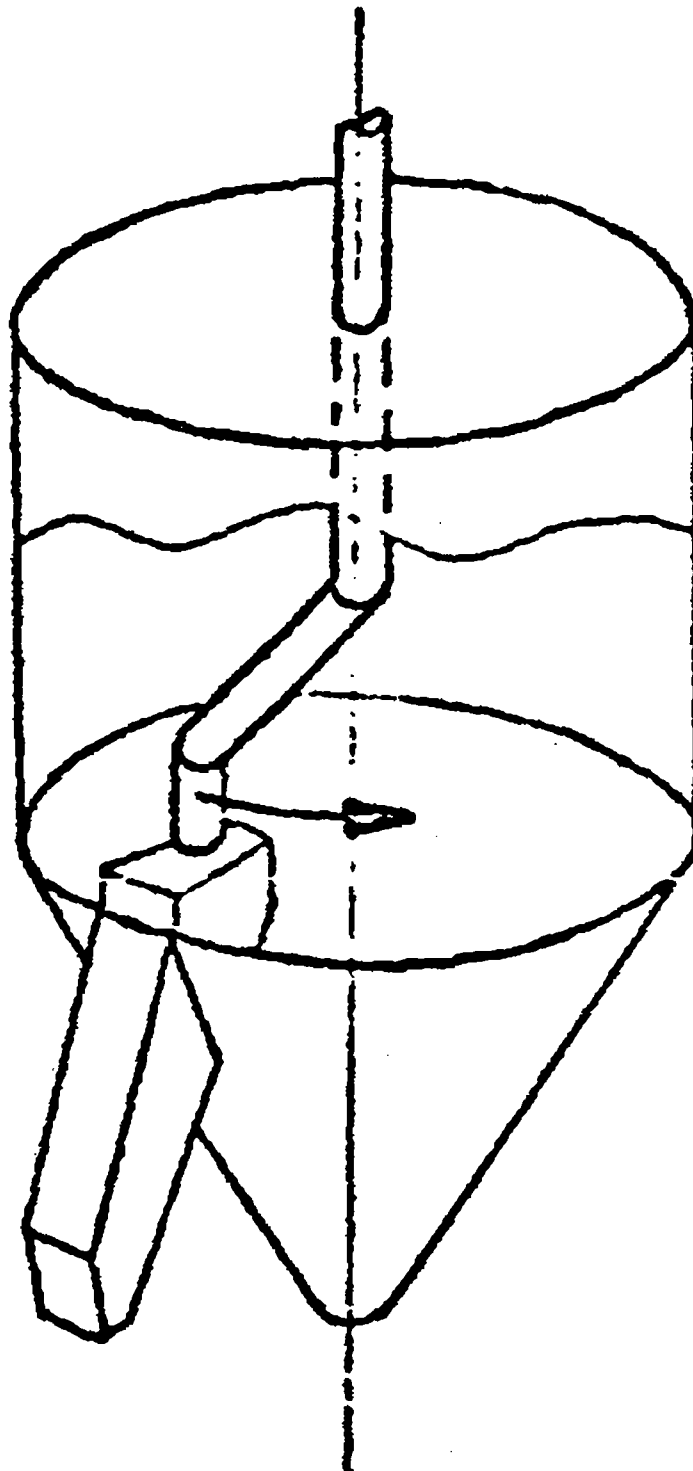
This type, when suitably adjusted for the materials properties, is precise and produces no systematic errors. The equipment is of excellent design by virtue of the small drop height of the material and allows the possibility to remove the sample immediately.

3.2.2 Vézin - Sampler



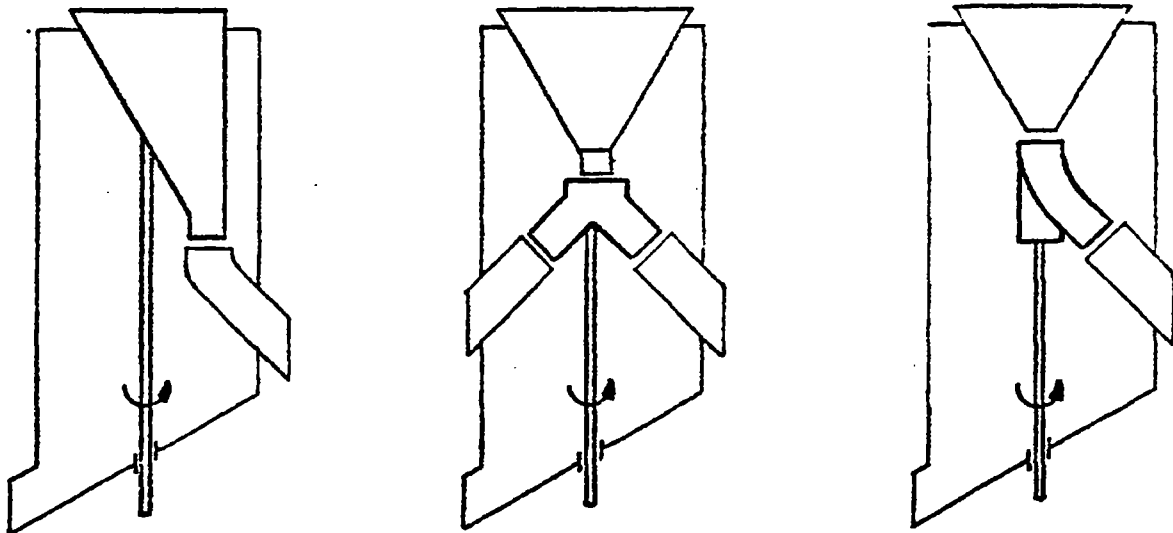
The design concept of this equipment is correct. It is unsuitable for installation at a discharge point, but rather for small material flows of relatively fine grained dry solids or for slurries. One advantage is the good separation of the sample from the remaining material.

3.2.3 Sampler with rotating distributor



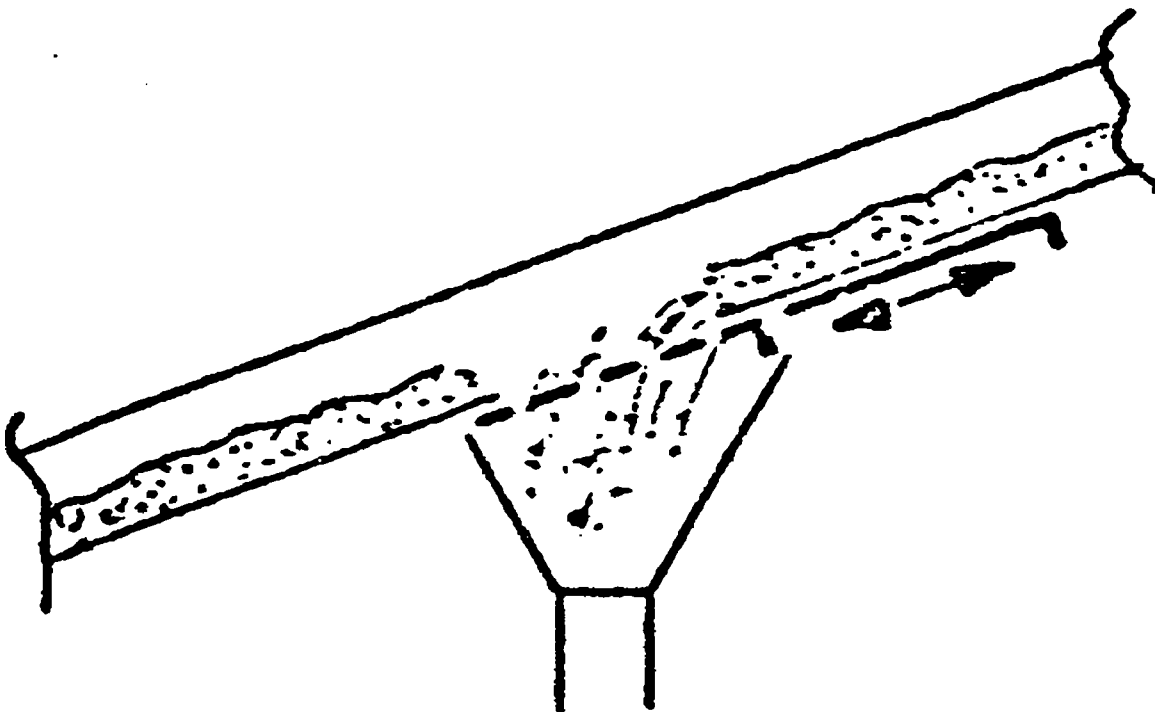
This type has been developed from the Yezin sampler by means of exchanging the rotating and stationary parts, and is therefore correct in its concept and principle. Due to the relatively high position of the distributor tube, the material reaches the sampler aperture at a high velocity. This is unfortunate when taking the sample and creates some dust. Furthermore, a demixing process does take place in the drop tube due to the considerable centrifugal forces present.

Further variations of this type are shown in the sketches below.

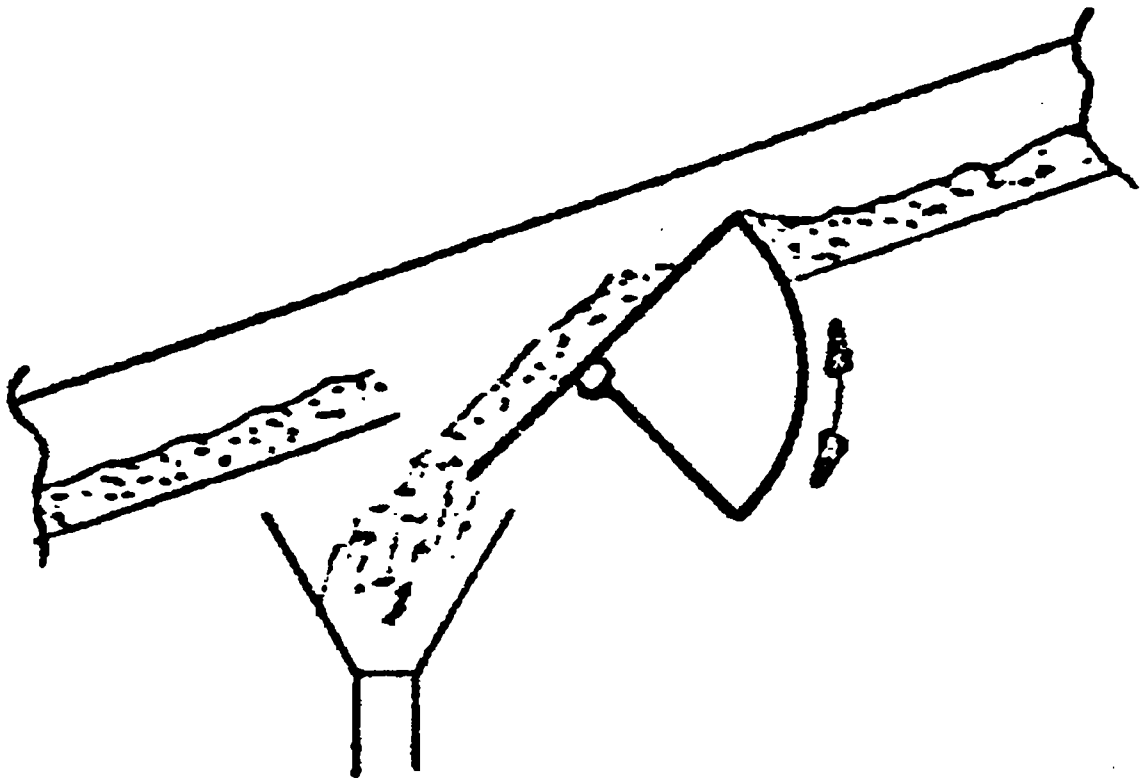


All these types suffer from the disadvantage that the whole mass of the undivided sample has to be accelerated.

#### 3.2.4 Slides and flaps in ducts



In the case of the transport of bulk materials having a low bed depth, this sampling equipment may be sufficient.



The material lying on the flap is extracted whilst the oncoming material is stopped during the sampling. Provided the material does not stick, and provided that the dimensions have been well-chosen, this sampler is just right and delivers reproducible samples.

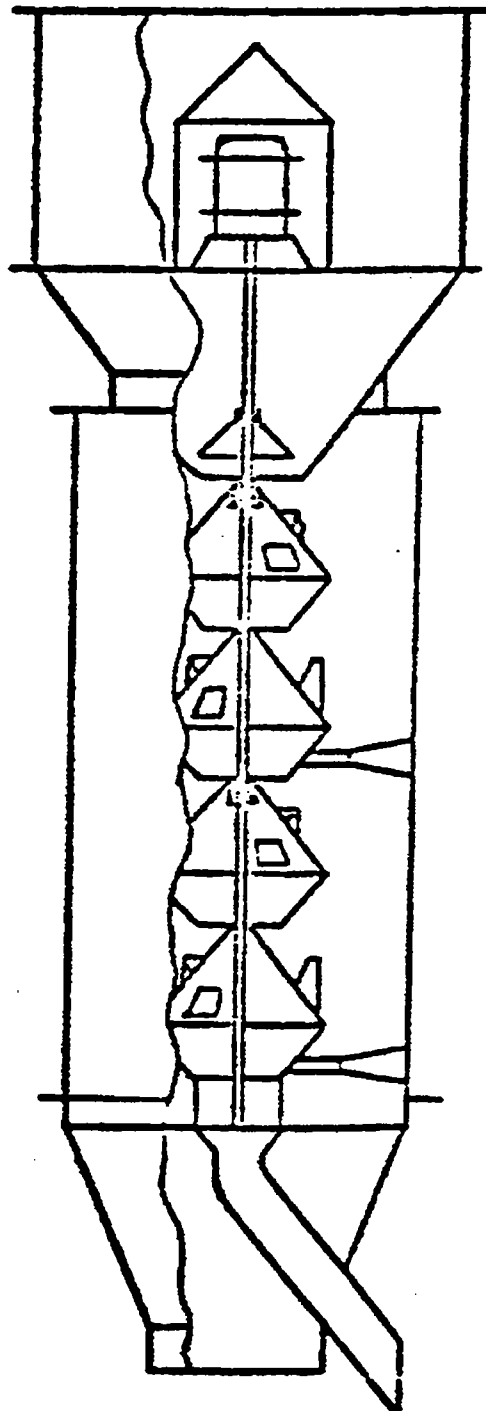
### **3.3 Equipment for Longitudinal Samples**

#### **3.3.1 Multi-stage sample divider**

This type of equipment has been extensively used in the past and is still in frequent use to reduce the quantity of samples. It consists of several vertically orientated samplers. That alone has two disadvantages:

- 1) The equipment requires considerable height for its installation and
- 2) the dust which is created by the partial free fall of the material is ducted upwards due to the chimney effect of the closed vertical casing, so that the sample on the bottom is lacking in the finest particle sizes.

A known representative of this type is the "Koulakoff-Divider". It consists of a series of rotating and stationary double cones.

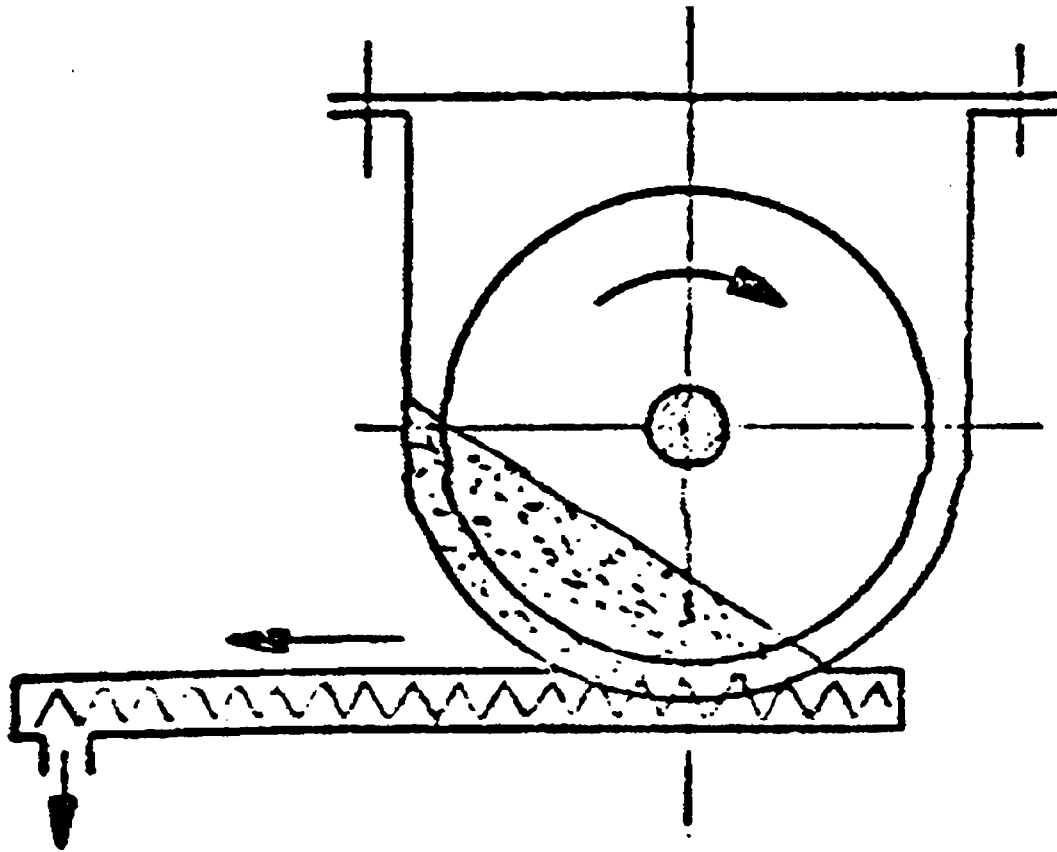


The ratio of partition can be widely varied through an increase or decrease of the number of steps. It can also obtain very large values. By means of precise tests, Pierre Gy was able to establish a systematic error of up to 20% using this equipment, caused by selective sampling of the various particle sizes.

Because of this considerable systematic error, the Koulakoff divider cannot be recommended for use in sample preparation.

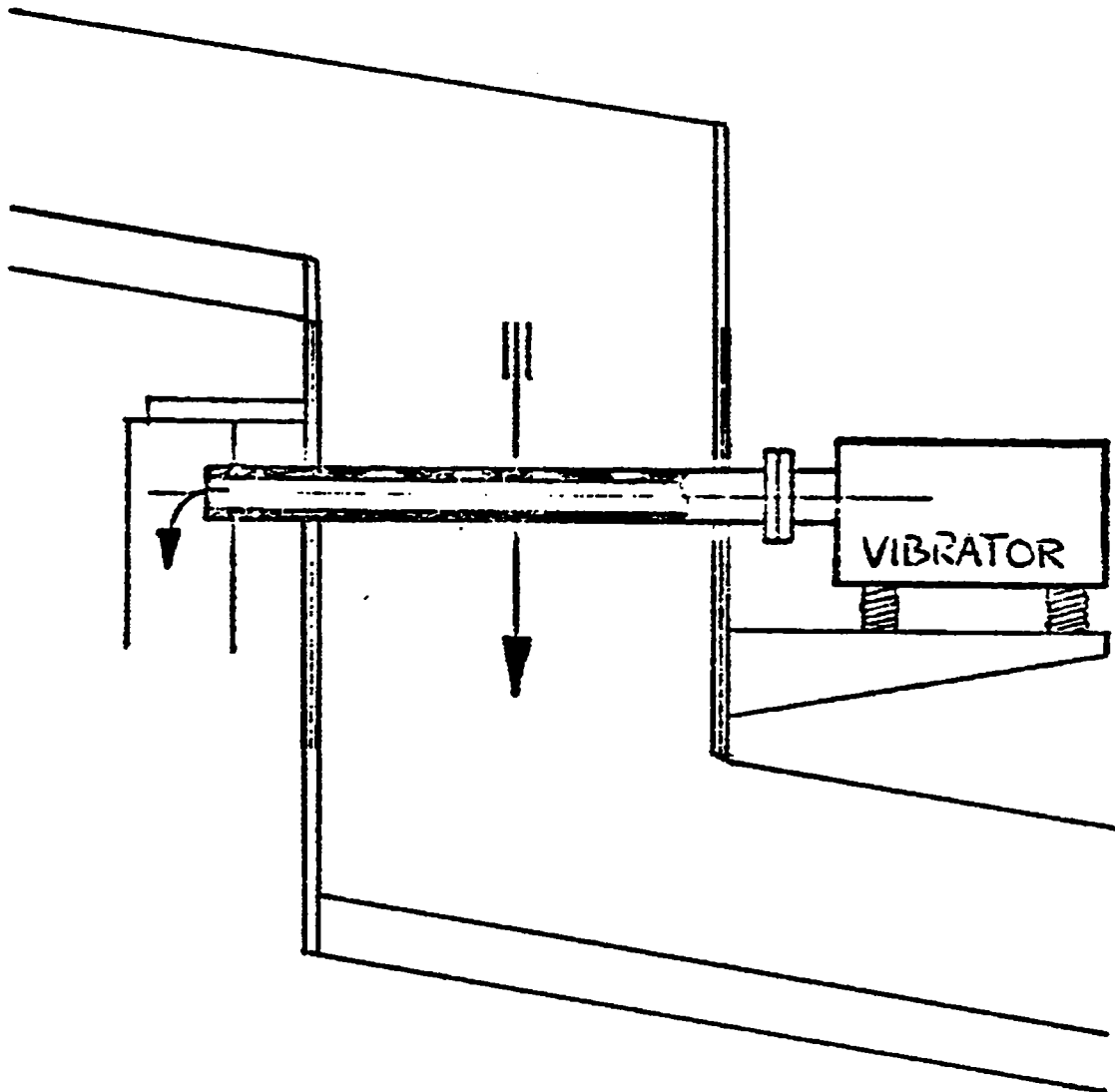
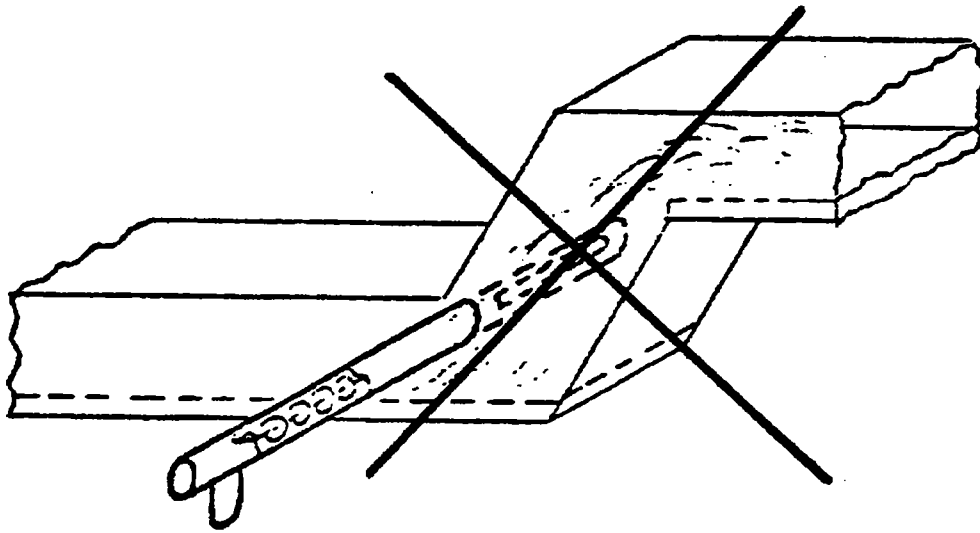


3.3.2 Sampling from screw conveyor



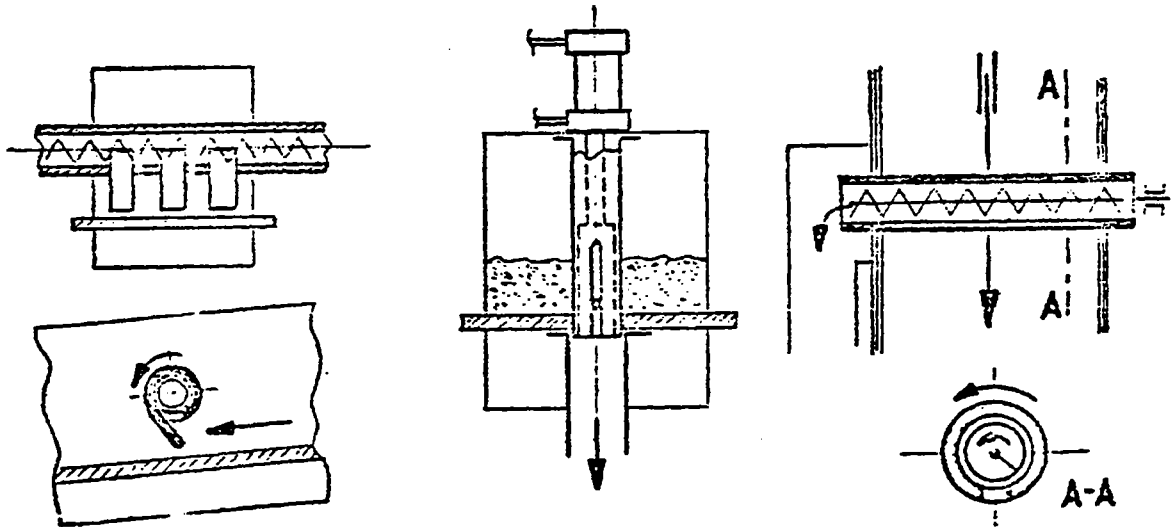
This type of sampling screw continuously takes part of the whole of the flow, therefore providing a longitudinal sample. As the material layer in a screw conveyor is heterogeneously distributed, this sampler will create a systematic error and therefore can not be recommended.

3.3.3 Sampling from a meal transfer chute



**3.4 Equipment for Quasi-Point Samples**

The same comments which were made for the category of section 3.3, are also valid for this class. The samples are only representative if the material is homogeneous which is mostly not the case shortly after a transfer station or a change in direction. Whether equipment of this type should be declined as a matter of principle depends mainly on the use to which it is put. In the sampling of fine meal and small grained bulk material, in which the units to be measured are not a function of the particle size, the resulting systematic errors can be ignored. In each case, however, it would be more elegant to install a sampler more suited to the material conditions. There now follows a few examples of meal samplers, which obtain quasipoint samples.

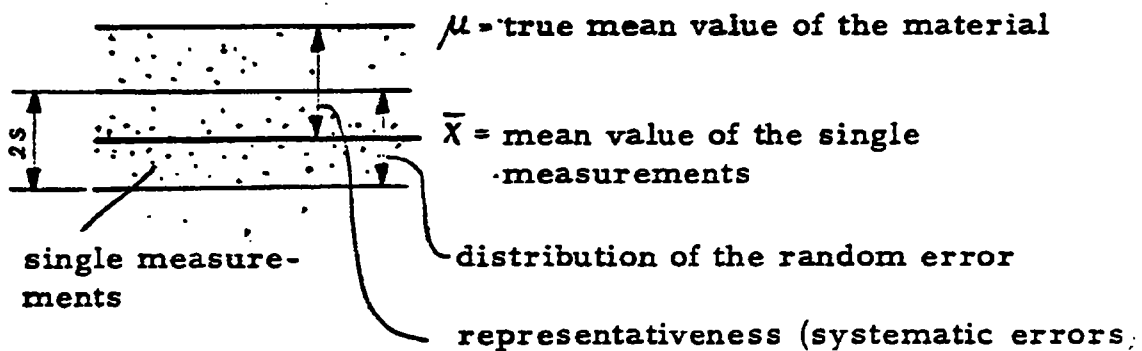


**3.5 Experimental Assessment of Samplers**

This chapter does not go into the process of defining the precision of the results for samplers or sampler systems, but limits itself to referring to the already mentioned book by Pierre Gy. We only wish to touch briefly on two elements of precision namely representativeness and distribution of accidental errors.

The term representativeness has already been mentioned and signifies the difference of the true mean value  $\mu$  of the material and the mean value  $\bar{x}$  of the single measurements. A representative sample is only obtained if the total sample error has a random variation with the mean value of 0 or in other words, if no systematic error appears. The distribution of the random error describes the reliability of the sampling. It is independent of the representativeness and can, for an example, be very small, even if  $\bar{x}$  and  $\mu$  are not the same. The illustration below attempts to explain these two expressions.

It is necessary to keep both terms strictly separated, and the appropriate methods must be applied to determine them. It must be further stated that here an experimental assessment of a sampling plant will cost a great deal of work and care, when done correctly.



#### **4. HOW TO IMPLEMENT AN ADEQUATE SAMPLING SYSTEM**

For the design or selection of an appropriate material sampler which satisfies the plant-specific requirements, the following aspects must be considered:

- ◆ flow sheet, layout and detailed drawings of the area in question
  - definition of the proposed sampling point and its position within the circuit
  - space available
  - definition of potential criteria
- ◆ process-oriented criteria with regard to the potential sampling point
  - flow rate of material (t/h)
  - velocity of material (m/s)
  - pressure (in case of a closed system)
  - rate of sampling (kg/h)
  - frequency of sampling
- ◆ physical description of material samples
  - type of material
  - screen analysis
  - density
  - moisture or water content
  - stickiness, dustiness, viscosity (slurry)
  - etc.

